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Predators of Enashiva: A Survey of Occurrence & Distribution

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SIT Study Abroad

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ABSTRACT:

This study was conducted during a period of 16 days (April 10 to April 26, 2011) at the Enashiva Nature Refuge in Northern Tanzania. It was a modified repeat study, using the same methodologies of a mammal survey conducted in November 2009, however this study only focused on occurrence and distribution of predators in the highest trophic level and accounted for reptile and birds, in addition to mammals. Based upon the findings of the November 2009 study, it was hypothesized that the woodland would have the highest predator species richness. This hypothesis was supported by the data; the woodland habitat had the highest alpha richness with a value of 20. All of the habitats were very diverse and the species diversity of Enashiva as a whole was also very high with a value of 0.884. The five different habitat classifications of Enashiva were fairly unique, with the grassland and woodland habitats sharing the highest number of common species. A simultaneously conducted survey on mammals below the highest trophic level found the highest abundance of herbivores in the grassland, which may explain the higher similarity between the grassland and woodland as predators may travel between the woodland to rest and the grassland to hunt. The observed distribution of mammalian predators was consistent with scientific literature on the topic. Furthermore, the survey of mammals in the lower trophic levels found the highest abundance of Thomson's gazelle, which Leighton-Jones (2002) found to be the only common prey hunted by all lions, leopards, hyenas, and cheetahs. This is important because a high, stable population of Thomson's gazelles in Enashiva could potentially increase the populations of resident predators as the resource base available to them expands, creating a more stable environment. Viable predator populations play an important role in drawing tourists to the refuge as well as in the overall conservation of the savanna ecosystem: by maintaining populations of species in the lower trophic levels, predators inherently maintain stability within the trophic levels, by preventing trophic cascades, and maintaining an intermediate level of pressure on the resource base. Additionally, much of the research on carnivores in the savanna has only been conducted on vulnerable species, such as cheetahs, but there has not been a strong focus on carnivores as a whole, especially in recovering conservation areas, so this study is important in order to help contribute to the existing knowledge on the topic.

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INTRODUCTION:

Across the world, with populations increasing exponentially, humans are rapidly changing their environments to adjust to expanding pressure for food, land, and water for subsistence. While this rapid expansion is in many ways inevitable, it has also resulted in widespread fragmentation of habitats many wild species depend on to survive, creating islands of suitable habitat across many regions of the world. Within Eastern Africa in particular these islands can often inhibit movement of animals that is essential for them to find new sources of food and water. With most animal populations decreasing in this region, different approaches to wildlife conservation are emerging and gaining more momentum. In Tanzania, the privatization of conservation is becoming the primary approach to address the issue of declining populations. By privatizing land for conservation purposes, the fragmented landscapes many animals have to cross for migration purposes between national parks will, in theory, be better protected. Furthermore, because the private landowners' businesses are dependent on stable animal populations, the landowners will have an incentive to maintain suitable habitat for these animals. Privatizing conservation also has the benefit of relieving some of the financial burden from the Tanzanian government. Particularly through auctions, private parties such as safari companies and conservationists are able to lease land from the Tanzanian government and then transform the area into private game reserves, nature refuges, or conservation areas.

An example of this is the establishment of the Enashiva Nature Refuge by the Thomson Safari Company. Enashiva is a 12,600-acre nature refuge just outside of the Serengeti National Park. The land was auctioned off and leased to Tanzania Conservation, Ltd., an organization established by Thomson Safari, in 2006. Before this time, the land was controlled by Tanzania Breweries, Ltd. and used for barley farming. Since Enashiva was historically used for agricultural purposes its establishment as a nature refuge has allowed its natural savannah ecology to regenerate and recover with wildlife populations in the area having more than doubled and sightings of endangered species increasing (Yamat, pers. comm.). Enashiva also falls within the Serengeti-Mara ecosystem and therefore plays an important role as a migration corridor for the migrating herds of wildebeest in this region. Additionally, the Enashiva Nature Refuge is a conservation and tourism area and was established with a relatively unique management plan and goals, placing great importance on community based conservation and cooperation and in 2009 Thomson Safari was honored with the Tanzanian Conservation Award for wildlife conservation and community involvement (Yamat, pers. comm.).

The Serengeti-Mara ecosystem, which encompasses the Enashiva Nature refuge, is characterized by a savanna ecosystem. Savanna environments are classified by stochastic fluctuations of rainfall,

grazing, nutrient availability and fire (Gichohi 1996). All of these factors have made savannas very dynamic ecosystems, continually changing over time and space. In general, the savanna ecosystem is characterized by some trees and wooded plants, but is mainly dominated by an understory of grass. Enashiva Nature Refuge is considered to be a moist savanna because it receives a fair amount of rainfall during the two annual rainy seasons. Moist savannas tend to have high levels of primary productivity and biomass, although the vegetation is generally of lower nutritive value (Gichohi 1996). Many aspects of savanna ecology, including herbivory and fire, are attributed to the amount and intensity of rainfall and variation in soil nutrients (Gichohi 1996). Distribution of grazers and browsers in this ecosystem is influenced by the nutrient richness of the grasses they consume, which is a reflection of the nutrient availability in the soil. Because stochastic changes in the savanna occur over a large region, there is great variability in the nutrient richness of the grasses over time and ungulates have evolved to travel great distances in order to exploit these widely spaced hot spots of productivity (Gichohi 1996). Both large and small ungulates have also co-evolved with each other and other herbivorous animals in the savanna to develop very specialized niches and reduce competition among them. This niche specialization in the savannah has allowed for greater species diversity in the ecosystem.

Predation also plays an extremely important role in managing animal communities and species diversity. Morin (1999) defines predation as "the consumption of all or part of one living organism by another. Predation is operationally defined by a +/- interaction between an individual predator and prey, where the predator benefits from the interaction (+), while the consumed prey does not (-)." Additionally, predator-prey relations involve species, which occupy many different trophic levels including: herbivores consuming plants, carnivores consuming herbivores, carnivores consuming other carnivores, and parasites and parasitoids consuming hosts (Morin 1999). In the savannah ecosystem, lions, leopards, cheetahs, spotted hyenas, and wild dogs are the five most important large species of predator, although there are many more species occupying the top trophic levels that also contribute to the management of plant and animal communities. The Serengeti-Mara ecosystem in particular, hosts the largest occurrence of migrating ungulates and also one of the highest concentrations of large carnivorous predators in the world (Sinclair 1995). The impact of carnivorous predators on relative prey populations is highly dependent on the ratio of predator to prey and the degree of movement of prey. In systems where prey populations migrate, the impact of predators is limited by the certain times during the year when predator and prey occur together. However, where predator populations are greater, they may have a significant effect on local populations of prey (Gichohi 1996). Additionally, predation has also clearly had a significant impact on the evolution of second trophic level consumers, based on the

multiplicity of anti-predator adaptations. This points to the fact that predation, especially by carnivores, is a powerful agent of natural selection in the savanna ecosystem (Morin 1999). While there is not a high enough abundance of carnivores for any one species to act as the keystone species of the savannah ecosystem, predation by carnivores can still have the indirect effect of creating opportunities for a greater variety of species to occupy the same community by reducing the abundance of superior competitors (Morin 1999). Predator-prey relationships can also have indirect effects on their community through trophic cascades. A trophic cascade is the phenomenon in which the abundance of primary producers is indirectly impacted and regulated by top predators in an ecosystem with three or more trophic levels (Morin 1999).

By understanding how flora and fauna in every trophic level contribute to the management of their community, it is now possible to see how they all interact to create and perpetuate the savanna ecosystem. Therefore, by surveying the distribution and occurrence of third trophic level predators, coupled with information on the distribution, abundance, and diversity of all lower level consumers, one should be able to make a conclusion about the overall health of the ecosystem especially in a recovering nature refuge such as Enashiva. Previous surveys of the abundance and distribution of mammals and birds in the Enashiva Nature Refuge have been conducted over the past couple years. Thus, by focusing only on a certain trophic level in the area, it will be possible to expand the knowledge of the distribution and occurrence of resident fauna and draw conclusions about the overall status of Enashiva as a nature refuge currently. Therefore, this study will solely concentrate on the distribution and occurrence of predators, but in the discussion it will be possible to draw on the results of other ongoing studies to make conclusions about Enashiva as a whole.

A mammal study and a bird study were previously conducted in November 2009. The mammal survey recorded 23 total species: 22 species in the woodland, 16 species in the wooded grassland, 10 species in the grassland, 5 species in the ridge woodland, and 6 species in the riverine woodland. The bird survey recorded 124 different species: 56 species in the woodland, 64 in the wooded grassland, 33 in the grassland, and 61 in the riverine habitat. This study will essentially be a replicate study with some modifications in order to examine the distribution and occurrence of top-level trophic consumers by habitat type within the Enashiva Nature Refuge. Based on the results of the previous study (i.e. a high density of species in the woodland habitats) it is hypothesized that the highest occurrence of carnivorous species will be observed in the woodland, with the assumption that a lower alpha richness of avian species was observed in the woodland because of reduced visibility by the thicker vegetation.

STUDY SITE DESCRIPTION:

The study was conducted at Enashiva Nature Refuge, which borders the Serengeti National Park in Northern Tanzania. At an elevation that ranges from 2010 to 2344 meters above sea level (Yamat, pers. comm.) Enashiva is comprised of five different habitat types: woodland, grassland, wooded grassland, riverine woodland, and ridge woodland. Habitats were defined using guidelines outlined by Pratt and Gwynne (1977).

Woodlands consisted mainly of trees up to 20 meters high with an open or continuous canopy accompanied by an understory of grasses and brushy growth. The grasslands were dominated by a variety of grasses with some shrubs. Wooded grasslands were made up of scattered trees and an understory of grass; the trees were always prominent, even though the canopies rarely connected. The ridge woodland was composed of short trees and vegetation on rocky slopes with an incline of approximately 20°. The riverine woodland was classified as the habitat on the banks on either side of a river bed, including the bed itself, regardless of whether it carried water at the time of the transect. The habitat extended about 5 to 10 meters on either side of the river, marked by the presence of hydrophilic vegetation species such as Yellow Fever Acacias, *Acacia xanthopholea*. Over the past ten years, rainfall patterns in the region have been relatively unpredictable, with some years experiencing plenty of rain and other years being relatively dry; this year, rainfall has been fairly sporadic and light. This study was conducted during the rainy season, however it only rained on three separate occasions in a span of 20 days.

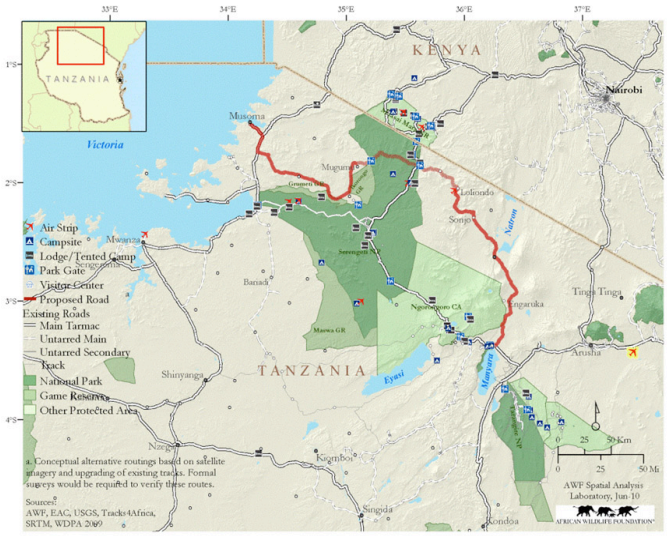

Figure 1. Map of Loliondo Region of Northern Tanzania where study was conducted. Data were collected using 32 walking transects April 10 to April 26, 2011, Enashiva Nature Refuge, Tanzania.

METHODS:

A survey of top trophic level consumers was conducted within the Enashiva Nature Refuge. The sample frame of the study was all animals in the top trophic level in Northern Tanzania and the sample population was those upper level consumers observed in Enashiva from April 10, 2011 to April 26, 2011.

A previous survey of all diurnal mammals was conducted within the Enashiva Nature Refuge in November 2009; this study was a modified repeat study using the previously established methodologies and sample areas, which were chosen using systematic random sampling. Walking transects were used to collect data, with the intent to maximize the total area of Enashiva surveyed. Two survey periods were conducted every day, one in the morning and one in the afternoon, when the wildlife were the most active, for 16 days, with a total of 32 resulting transects. While, the starting times, ideally, were 7:30 for the morning survey and 4:00 for the afternoon survey, the actual starting times ranged from 7:45 to 8:20 in the morning and 3:30 to 4:20 in the afternoon.

The transects were 11.25° apart, radiating out from camp. As a result of the location of camp and the shape of the Enashiva Nature Refuge, a line was drawn running through camp from due North (0°) to due South (180°). The transect aligned with 0° was not surveyed due to its close proximity to Enashiva's western border (Figure 2).

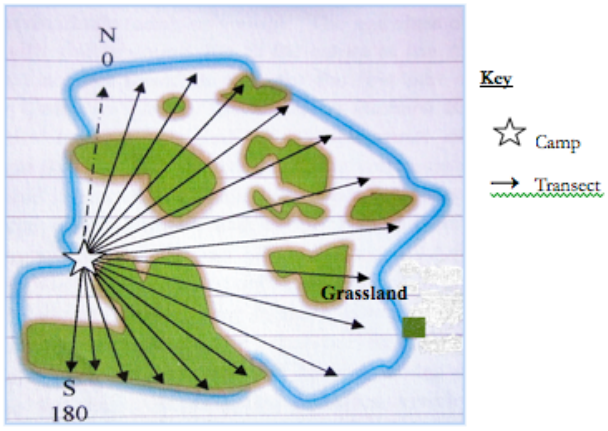

Figure 2. Visual representation of the 16 transects (11.25° apart) used during the survey of predator species in the Enashiva Nature Refuge. Transect aligned with 0° (North) was removed due to its close proximity to the western border. Data were collected using 32 walking transects April 10 to April 26, 2011, Enashiva Nature Refuge, Tanzania.

Data were collected over a period of 16 days, split into two periods, the first 8 days (16 transects) and the second 8 days (16 transects). In order to reduce the time of day bias, the transects walked in the morning during the first period were walked in the afternoon during the second period and vice versa. The order of the transects was selected randomly with the stipulation that no two neighboring transects would be surveyed on the same day in order to reduce the possibility of double-counting individuals in the sample population.

A compass was used to orient each transect and a GPS unit was used to measure the length of each transect surveyed, in order to calculate each area surveyed. The belt transects used to survey Enashiva had two widths: the first width was the physical width of the road from which animal tracks and scat were observed and the second width varied with visibility in each habitat type as dense vegetation inhibited visibility in terms of distance. The maximum width was established using a rangefinder, maximum width was recorded as 500 m to each side of the belt transect for primary observations and 1 m for tracks and signs.

As the belt transects were walked, 180° visual scans were completed by one person and another scanned the ground for spoor and other signs of predator occurrence. All of the 16 transects were walked with another researcher, however she focused primarily on mammals below the highest trophic level. For top trophic level consumers observed within the bounds of the transects the following data was recorded: time of day, habitat type, species, number of individuals, sex of individuals (when possible), age class of individuals (adult or young), and whether the observation was primary or secondary. The age class of an individual was determined only for species with visible young primarily because the study was a topical visual survey. Young were defined by the individual's relative size, with the assumption that animals counted as young were smaller and not yet of reproductive age. Humans will not be included in the data collection.

After data collection was completed, several modes of descriptive analysis were used to summarize the data. Occurences, species richness, community similarity, and Simpson's Index of Diversity were calculated for Enashiva as a whole and for the various habitats. An additional analysis was conducted to compare the occurrence and distribution of different classes of predators (e.g. mammals, reptiles, and birds).

SELECTED RESULTS:

Data were collected over a period of 16 days at the Enashiva Nature Refuge in Northern Tanzania. The gamma (γ) richness of the study site was found to be 32 predator species. A total of 234 individual were recorded: 105 individuals were recorded through primary observation and 129 individuals were recorded through secondary observation (e.g. spoor, scat, etc). Of the 105 individuals observed primarily, 5 individuals were not positively identified. The 32 transects, which were walked to conduct the survey, covered a total area of 19.54 km^2 over five different habitats; grassland, wooded grassland, and woodland were the three dominant habitat types and were surveyed the most (Figure 3).

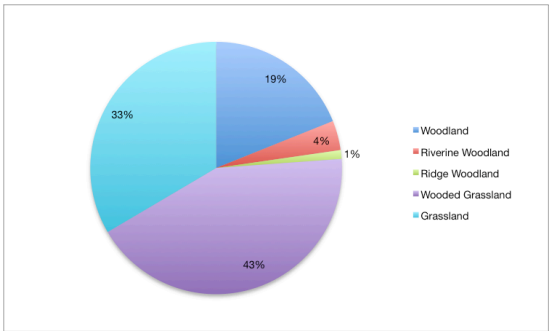

Figure 3. Percentage of total area (19.54 km^2) surveyed by habitat type: woodland, riverine woodland, ridge woodland, wooded grassland, and grassland. Data were collected using 32 walking transects April 10 to April 26, 2011, Enashiva Nature Refuge, Tanzania.

The alpha (α) richness of the woodland was 20, 6 for the riverine woodland, 9 for the ridge woodland, 16 for the wooded grassland, and 15 for the grassland (Figure 4).

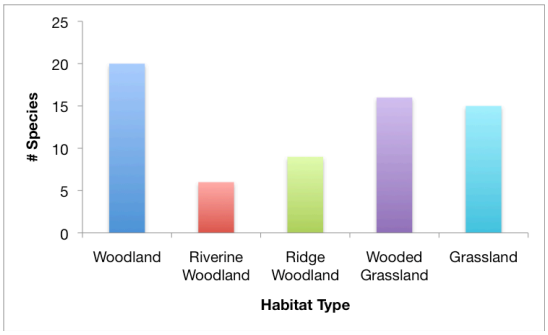

Figure 4. Occurrence of predator species by habitat type (α richness): woodland (n=20), riverine woodland (n=6), ridge woodland (n=9), wooded grassland (n=16), and grassland (n=15). Data were collected using 32 walking transects April 10 to April 26, 2011, Enashiva Nature Refuge, Tanzania.

The Simpson's Index of Diversity (SID) was calculated for the area of each habitat type surveyed within the Enashiva Nature Refuge and for the total area surveyed (Table 1).

Table 1. Simpson's Index of Diversity calculated for distribution of top trophic level consumers. Data were collected using 32 walking transects April 10 to April 26, 2011, Enashiva Nature Refuge, Tanzania.

Habitat Type	Simpson's Index of Diversity
Woodland	0.874
Riverine Woodland	0.671
Ridge Woodland	0.769
Wooded Grassland	0.875
Grassland	0.874
Total	0.884

Community similarity was calculated for each of the habitat types surveyed within the Enashiva Nature Refuge. Woodland and riverine woodland habitats were 9.09% (4/22) similar, woodland and ridge woodland were 31.8% (7/22) similar, woodland and wooded grassland were 44% (11/25) similar, woodland and grassland were 52.2% (12/23) similar, riverine woodland and ridge woodland were 25% (3/12) similar, riverine woodland and wooded grassland were 15.8% (3/19) similar, riverine woodland and grassland were 23.5% (4/17) similar, ridge woodland and wooded grassland were 19% (4/21) similar, ridge woodland and grassland were 26.3% (5/19) similar, and wooded grassland and grassland were 29.2% (7/24) similar (Figure 5).

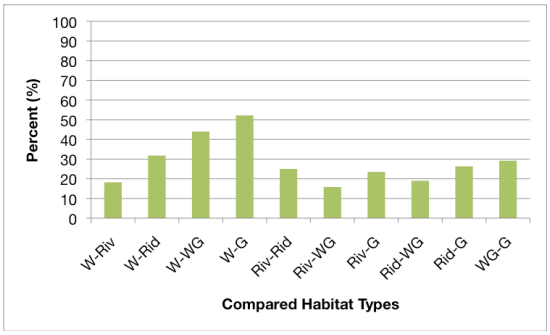

Figure 5. Community similarity, comparing the five different habitats of Enashiva Nature Refuge based on occurrence of a species in both habitat types. W: Woodland, Riv: Riverine Woodland, Rid: Ridge Woodland, WG: Wooded Grassland, G: Grassland. Data were collected using 32 walking transects April 10 to April 26, 2011, Enashiva Nature Refuge, Tanzania.

The recorded predators observed both primarily and secondarily in the Enashiva Nature Refuge were classified in one of four different categories within the top-trophic level consumers: mammalian carnivores, mammalian insectivores, avian carnivores, and reptilian carnivores (Appendix A). Overall 7 mammalian carnivore species, 3 mammalian insectivore species, 19 avian carnivore species, and 3 reptilian carnivore species were found to occur in the Enashiva Nature Refuge. Only the wooded grassland and the grassland habitats were found to host all four classifications of predator (Figure 6). The woodland and ridge woodland were found to host mammalian carnivores, mammalian insectivore, and avian carnivores (Figure 6). The riverine woodland was only found to host mammalian carnivores and avian carnivores (Figure 6).

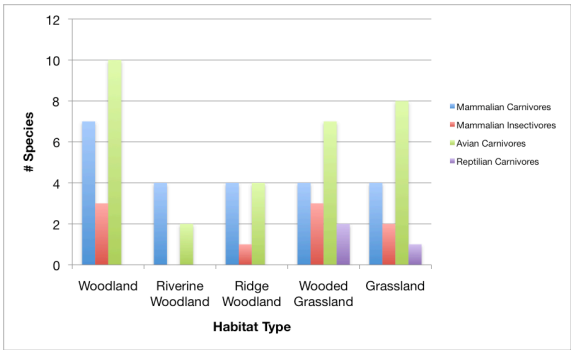

Figure 6. Distribution of species among the five different habitat types according to predator classification. Woodland: mammalian carnivores (n=7), mammalian insectivores (n=3), avian carnivores (n=10). Riverine Woodland: mammalian carnivores (n=4), avian carnivores (n=2). Ridge Woodland: mammalian carnivores (n=4), mammalian insectivores (n=1), avian carnivores (n=4). Wooded Grassland: mammalian carnivores (n=4), mammalian insectivores (n=3), avian carnivores (n=7), reptilian carnivores (n=2). Grassland: Mammalian carnivores (n=4), mammalian insectivores (n=2), avian carnivores (n=8), reptilian carnivores (n=1). Data were collected using 32 walking transects April 10 to April 26, 2011, Enashiva Nature Refuge, Tanzania.

The distribution and occurrence of predator species in the Enashiva Nature Refuge within each of the four predator classifications were analyzed, but due to low population numbers avian and reptilian carnivore data was not included in the results. Nevertheless, 19 species of avian carnivores were observed during the study and 3 species of reptilian carnivores were observed (Appendix A). Seven mammalian carnivore species were found to occur in the Enashiva Nature Refuge: lion, leopard, cheetah, hyena, caracal, serval, and jackal (Figure 7). Hyena had the highest frequency of occurrence across all habitat types, except for the grassland, where jackals were most abundant (Figure 7).

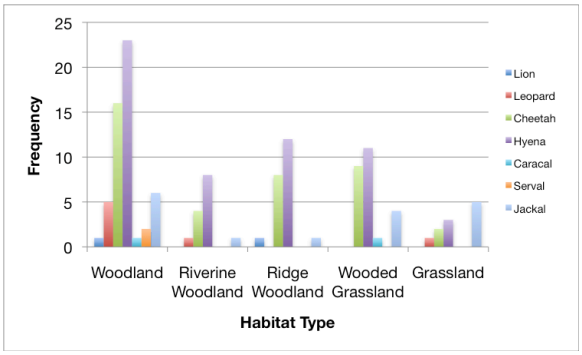

Figure 7. Distribution of mammalian carnivores by observed occurrence within the five habitat classifications. Lion: woodland (n=1), ridge woodland (n=1). Leopard: woodland (n=5), riverine woodland (n=1), grassland (n=1). Cheetah: woodland (n=16), riverine woodland (n=4), ridge woodland (n=8), wooded grassland (n=9), grassland (n=2). Hyena: woodland (n=23), riverine woodland (n=8), ridge woodland (n=12), wooded grassland (n=11), grassland (n=3). Caracal: woodland (n=1), wooded grassland (n=1). Serval: woodland (n=2). Jackal: woodland (n=6), riverine woodland (n=1), ridge woodland (n=1), wooded grassland (n=4), grassland (n=5). Data were collected using 32 walking transects April 10 to April 26, 2011, Enashiva Nature Refuge, Tanzania.

Three mammalian insectivore species were found to occur in the Enashiva Nature Refuge: bat-eared fox, banded mongoose, and an unidentified species of mongoose (Figure 8). No mammalian insectivores were observed in the riverine woodland habitat (Figure 8). Banded mongoose was the most abundant species in the woodland and wooded grassland, while the bat-eared fox was the most abundant in the grassland (Figure 8). Only the unidentified species of mongoose was observed in the ridge woodland (Figure 8).

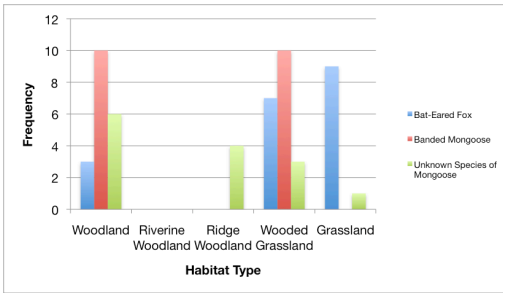

Figure 8. Distribution of mammalian insectivores by observed occurrence within the five habitat classifications. Bat-eared fox: woodland (n=3), wooded grassland (n=7), grassland (n=9). Banded Mongoose: woodland (n=10), wooded grassland (n=10). Mongoose: woodland (n=6), ridge woodland (n=4), wooded grassland (n=3), grassland (n=1). Data were collected using 32 walking transects April 10 to April 26, 2011, Enashiva Nature Refuge, Tanzania.

DISCUSSION:

Species Richness

The hypothesis that the highest occurrence of carnivorous species would be observed in the woodland was supported by the findings. The woodland habitat had the highest alpha richness with a total of 20 different species of predator and the wooded grassland habitat was found to have the second highest alpha richness with a value of 16, followed by the grassland with a value of 15 (Figure 4). A total area of 19.54 km^2 was surveyed during the study period, with 43% (8.34/19.54) of the total area comprised of wooded grassland habitat, 33% (6.54/19.54) comprised of grassland habitat, and 18% (3.7/19.54) comprised of woodland habitat (Figure 3). Therefore, even though the woodland habitat possessed the highest alpha richness of all the five different habitat types, it was not the most dominant habitat surveyed, suggesting that the amount of time spent in the woodland habitat did not influence the observed alpha richness positively. However, the high alpha richness of the wooded grassland and grassland habitats may have been a result of them constituting a higher percentage of the total area surveyed. Furthermore, when the alpha richness of each habitat type is assessed within the separate predator classifications, specifically mammalian carnivore and mammalian insectivore, the woodland habitat retains the highest alpha richness with a total of 7 different mammalian carnivores (Figure 6), but when considering mammalian insectivore species the woodland and wooded grassland both contained the highest alpha richness of 3 (Figure 6).

Species Diversity

The data suggests that the five different habitat types of the Enashiva Nature Refuge are very diverse; the wooded grassland had the highest species diversity with a Simpson's Index of 0.875 (Table 1). The woodland and grassland both had the second highest species diversity with a Simpson's Index of 0.874 (Table 1). The marginal difference in the Simpson's Index between the wooded grassland and the woodland and grassland could be a result of the wooded grassland being the dominant habitat surveyed or the fact that a lower abundance of trees led to improved visibility of individuals, increasing the likelihood of seeing more species in the wooded grassland. The ridge woodland had the third highest Simpson's Index of Diversity with a value of 0.769, followed by the riverine woodland with a value of 0.671 (Table 1). The riverine woodland accounted for only 4% (0.74/19.54) of the total area surveyed (Figure 3), which could explain why it had the lowest index of diversity. Overall, the Simpson's Index of Diversity for predator species in the Enashiva Nature Refuge is high, with a value of

0.884, higher than any of the indices of diversity for the individual habitat types. It is also important to note that 19 of the 32 top trophic level consumers found to occur in the Enashiva Nature Refuge were avian carnivores (Appendix A) and for the majority of these species only a few individuals were observed, so while the diversity of species is high, the nature of this study did not lend itself to assessing actual abundance and population dynamics. It would be interesting to conduct an additional study to further examine just how prominent predator species are in the Enashiva Nature Refuge. Additionally, there are a number of animals, which have been found to occur in the Serengeti, but were not observed in Enashiva during the length of this study (Appendix B). They may have failed to be observed simply because they are not resident predator species in the nature refuge, or because their spoor or scat was not seen or was misidentified as another species. A more extensive, follow-up study is suggested in order to sufficiently index and identify all of the resident predator species in the Enashiva Nature Refuge.

Community Similarity

In terms of community similarity, all five different habitat types were relatively unique. The woodland and grassland habitats had the highest similarity with 52.2% (12/23) of the species occurring in both the habitats being the same (Figure 5). The woodland and wooded grassland habitats had the second highest value of similarity with a 44% (11/25) overlap of species found in each habitat (Figure 5); because this value is less than 50% it is considered to be relatively low. Riverine woodland and wooded grassland were the least similar, with only 15.8% (3/19) of the total species occurring in both habitat types. The low community similarity between the habitat classifications reflects just how the spatial heterogeneity characteristic of the savanna ecosystem creates many different habitats to support diversity specific to each habitat. It is interesting that of all the five different habitat types, the woodland and grassland were the most similar especially when the landscape of each habitat is considered: woodlands consist mainly of trees up to 20 meters high with an open or continuous canopy accompanied by an understory of grasses and brushy growth and grasslands are dominated by a variety of grasses with some shrubs. Because the grassland and woodland are so drastically different, one would expect the animals living in each of these habitats to also be very different in terms of their occupied niche. However, the common species in the woodland and grassland were the leopard, cheetah, hyena, jackal, bat-eared fox, unidentified species of mongoose, common buzzard, black-chested snake eagle, tawny eagle, black-shouldered kite, secretary bird, and unidentified raptor. The occurrence of the avian carnivores observed in the woodland and grassland may be explained by the fact they have relatively

large ranges and also may travel between the grassland to hunt and the woodland to roost. When considering the distribution of mammalian carnivores among the woodland and grassland habitats it is important to take into consideration the fact that the majority of the prey species graze and browse in the grassland, and as a result this is most likely where most of the hunting occurs; a simultaneous survey of all diurnal mammals below the top trophic level was conducted during the same period as this survey and found that the density of individuals was highest in the grassland (Appendix C). Additionally, the visibility of spoor in the woodland was much increased due to a reduction in vegetatative ground cover, such as grass, and a higher presence of bare ground. While in the grassland, visibility of spoor was mainly limited to times when the transect intersected the dirt road, otherwise observation consisted of discovering and identifying scat or other markings created by predators or primary observation of individuals. Therefore, these limitations and biases may have skewed the recorded observations of predators in the woodland and grassland habitats of the Enashiva Nature Refuge.

Distribution & Occurrence of Mammalian Predators by Species

The spoor of a lion was observed in the woodland once and the wooded grassland once (Figure 7). Although the recorded frequency of occurrence of lions is in no way a representative sample, the data suggest that lions may have an affinity toward woodlands and intermediate woodlands, especially for resting. It is also important to note that lions have a large territorial range and prefer open grassland habitat for hunting (Leighton-Jones 2002); the survey of lower trophic level consumers found the highest density of individuals in the grassland habitat, followed by the wooded grassland habitat (Appendix C). Further studies should be conducted to successfully analyze the distribution of lions within the Enashiva Nature Refuge.

Signs of a leopard were observed 5 times in the woodland, once in the riverine woodland and once in the grassland (Figure 7). The occurrence of the leopard species in the woodland and riverine woodland were all observed through spoor in the dirt, mud, and sand. The occurrence of the leopard species in the grassland was noted by deep scratch marks in the bark of an isolated tree in a plain on the eastern side of the refuge. In Richard Estes' *Behavior Guide to African Mammals* (1991) he notes that "The leopard is successful wherever diversified habitats afford a variety of small to medium-sized animals" additionally, "Large trees with inclined trunks or big branches 2-3 m from the ground are preferred scent posts. Here, a leopard pauses to sniff at previous scratch marks, stretches out along the branch or trunk, and 'sharpens' its own foreclaws." These explanations of leopard distribution and social behavior help to explain the observed occurrences of the leopard in the woodland, riverine woodland and the

grassland. Furthermore, because the highest density of mixed feeders, browsers, and grazers was observed in the grassland, it may be possible to infer that the leopard was simply moving between the woodland and riverine woodland habitats in order to reach the grassland to hunt.

The cheetah was observed secondarily, through its spoor and droppings, in all five different habitat classification. Cheetah spoor and droppings were observed most frequently in the woodland, 16 times, followed by 9 times in the wooded grassland, 8 times in the ridge woodland, 4 times in the riverine woodland, and 2 times in the grassland (Figure 7). Cheetahs have been found to have a very large territorial range; in the Serengeti, particularly, the areas defended by cheetah males were found to be 39-78 km^2 (Estes 1991), which can explain their high relative occurrence among all of the habitats, especially in the Enashiva Nature Refuge, which is relatively small in comparison to the Serengeti.

Hyena had the highest frequency of observation of all the predator species surveyed. Hyena followed a similar pattern to the cheetah with 23 observed occurrences of hyena in woodland, 11 in the wooded grassland, 12 in the ridge woodland, 8 in the riverine woodland, and 3 observed occurrences in the grassland (Figure 7). Hyenas have also been found to have a very large territorial range while following prey species and scavenging for carrion of other predators' kills and they have also been recognized as one of the most abundant carnivorous species in the Serengeti ecosystem (Hofer & East, 1995) so their high recorded occurrence is not unusual or surprising.

The caracal was only observed secondarily in the woodland once and in the wooded grassland once. While this is also in no way a representative sample, this explanation of caracal habitat preference seems to support the observation that caracals prefer woodland: "[Caracals] may venture into open grassland at night to hunt, but seem to require woody vegetation for cover, while avoiding dense evergreen forest" (Estes 1991).

Two secondarily observed occurrences of a serval were recorded in the woodland habitat. Caracal are said to occur especially along forest edges, and in areas of abandoned cultivation and secondary growth (Estes 1991), which is interesting to note, especially considering that Enashiva is a recovering nature refuge and was previously a barley farm.

In addition to cheetahs and hyenas, jackals were also found to occur in all of the five habitat classifications. The frequency of occurrence of jackals in the woodland was 6, followed by once in both the riverine woodland and ridge woodland, 4 in the wooded grassland, and 5 in the grassland (Figure 7). Jackals were the only mammalian carnivores to be observed primarily during the period of time when this study was conducted. In total, 7 jackals were observed primarily: 3 in the open grassland, 2 in the wooded grassland, 1 in the grassland close to the woodland habitat and 1 in the woodland close to the

grassland habitat. All of the observed occurrences of jackals in the riverine woodland and ridge woodland as well as the majority of observed occurrences of jackals in the woodland and wooded grassland habitats were secondary, consisting of scat and spoor; however, many of the observed occurrences were also near or within the ecotone of the woodland to the grassland. These observations seem to be supported by Estes (1991) who states that the "jackal occupies habitats intermediate between the plains… and the broad-leafed, deciduous woodland." However, interestingly the frequency of occurrence of the jackal in both the woodland and grassland were higher than in the intermediate habitat of the wooded grassland (Figure 7).

In terms of mammalian insectivores, the bat-eared fox was observed 3 times in the woodland, 7 times in the wooded grassland, and 9 times in the grassland the banded mongoose was observed 10 times in the woodland and 10 times in the wooded grassland and an unidentified species of mongoose was observed secondarily 6 times in the woodland, 4 times in the ridge woodland, 3 times in the wooded grassland, and once in the grassland. According to Estes (1991) "The bat-eared fox inhabits open grassland, light acacia woodland, and overgrazed rangeland…" This description of the bat-eared fox's preferred habitat type is supported by the data; after all, bat-eared foxes were observed in the highest frequency in the grassland, followed by the wooded grassland, and finally by the woodland. The banded mongoose seemed to convey an affinity toward wooded areas, which is confirmed by Estes (1991), "The banded mongoose is associated with wooded savanna… it avoids forests, but likes undergrowth and rarely ventures far into open country." The distribution of the unidentified species of mongoose is harder to analyze particularly because habitat preference is highly variable among the different species of mongoose. Furthermore, the spoor being less obvious or individuals being frightened off by the approaching surveyors could also explain the low frequency of observation of mammalian insectivores across all habitats, especially in the riverine habitat where no occurrences of mammalian insectivores were recorded. However, this could also be attributed to the riverine woodland comprising only 4% (0.74/19.54) of the total area surveyed.

Resident Predator & Prey Relationships

Overall, the Enashiva Nature Refuge was found to have a relatively high diversity of top trophic level consumers. This high diversity could be explained by the relative abundance of prey populations also residing on the nature refuge. The survey of all diurnal mammals below the top trophic level conducted during the same period recorded a total of 2985 individuals in Enashiva (Appendix C). Peter Leighton-Jones (2002) compared the major diet requirements and components of large savannah

carnivores and found that between leopards, cheetahs, lions, and hyenas their only common prey is the Thomson's gazelle. Interestingly enough, Thomson's gazelle was the most abundant species observed in the Enashiva Nature Refuge, with a total of 794 individuals (Appendix C). Taking into consideration the fact that Enashiva is a recovering nature refuge, where in 2006 it was very lucky to even see two zebra in one day (Yamat, pers. comm.) and this year 672 individuals were observed over a period of 16 days (Appendix C), animal populations are certainly increasing exponentially on the property. Furthermore, with resident prey populations on the rise, it can be inferred that the food resource base for predator species is also expanding, creating more suitable habitat for top trophic level consumers in the Enashiva Nature Refuge.

Resident populations of species below the highest trophic level are especially important in the conservation of predators and the savanna ecosystem as a whole because if resident prey populations decline below levels where viable populations of predator species can successfully hunt to sustain themselves, this could lead to a reduced presence of predators, resulting in a trophic cascade with populations of species in the lower trophic levels increasing exponentially and consequently increasing herbivory and pressure on their resource base. In particular, wildlife populations in the Serengeti appear to be relatively stable, but resident populations in the Northern Serengeti may be declining (Broten & Said, 1995). The viability of these resident herbivore populations in northern Serengeti poses the biggest threat to the success of resident predators in the region and overall ecosystem health. This relationship between resident predators and prey in the Northern Serengeti, exemplifies just how important it is to maintain viable levels of prey and suitable habitat for all animals through the promotion of conservation areas, such as Enashiva, in order to encourage predators to take up residence and help contribute to the balance of stable populations among all trophic levels.

BIASES, LIMITATIONS, & RECOMMENDATIONS:

- High variance between the composition of habitats of the total area surveyed, leading to some habitats being surveyed much more than others.
- Visibility of spoor in the dirt and sand was limited by vegetative ground cover, especially grass, in many areas.
- Difficult to equally budge time between looking for spoor and scat on the ground and physical predators in the habitat
- Bias toward clearer and larger tracks, which were easier to see.
- Visibility of individuals was limited by vegetation (e.g. high grass, bushes, etc)
- Noise generated by walking may have scared off many animals of interest, especially reptiles and snakes, resulting in a low-recorded frequency of occurrence.
- Spoor and scat of one species in a habitat may have only belonged to one individual, but was counted as two separate occurrences.
- Some observed spoor and scat might have been misidentified.
- Multiple forms of identification were used and sometimes were contradictory.
- Highly dependent on the guide for majority of identifications.
- More time is necessary in order to index a complete list of all the resident predator species and accurately assess the status of Enashiva as a recovering nature refuge.
- In the future, it may be better to specialize on a more specific classification of predator (e.g. mammal, reptile, bird, etc.).
- It would be interesting to conduct an additional study to further examine just how prominent predator species are in the Enashiva Nature Refuge, by assessing actual abundance and population dynamics.
- It would also be interesting to try and conduct a nocturnal study, as carnivores tend to be more active at night; this would lend itself to increased primary observations of mammalian predators, but reduced primary observations of reptilian and avian predators.

CONCLUSION:

The hypothesis was supported, with the highest alpha richness of predator species observed in the woodland habitat. Furthermore, when the alpha richness of each habitat type was analyzed by predator classification, specifically mammalian carnivore and mammalian insectivore, the woodland habitat retained the highest alpha richness with a total of 7 different mammalian carnivores (Figure 6), but when the mammalian insectivore species were analyzed by habitat, the woodland and wooded grassland both contained the same alpha richness of 3 (Figure 6).

Species diversity of each of the five habitat classifications was high with Simpson's Index of Diversity of 0.874, 0.671, 0.769, 0.875, 0.874, 0.884 for the woodland, riverine woodland, ridge woodland, wooded grassland, grassland, and Enashiva as a whole respectively (Table 1).

Community similarity between the different habitat types was relatively low, with the grassland and woodland being the most similar, sharing 52.2% (12/23) of the species occurring in both habitats (Figure 5). The low community similarity reflects how the savanna ecosystem's spatial heterogeneity is able to create many different habitats to support a wide diversity of animal life.

Overall, observed occurrence and distribution of surveyed predator species in the Enashiva Nature Refuge, especially mammalian predators, was supported by the scientific literature in terms of habitat preference for the species of interest (i.e. lion, leopard, cheetah, hyena, caracal, serval, jackal, bat-eared fox, banded mongoose, and an unidentified species of mongoose).

Furthermore, a survey conducted simultaneously on distribution and abundance of resident mammals below the highest trophic level found that herbivore populations are increasing in Enashiva (Appendix C). This is especially important for the conservation of predators and savanna ecosystem as a whole; if there is not a viable source of resident herbivore populations to support predator species, presence of predators could be reduced, resulting in a trophic cascade with populations of species in the lower trophic levels increasing exponentially, consequently increasing herbivory and pressure on the resource base.

As a whole, the status of Enashiva as a recovering ecosystem and nature refuge seems to be positive. With resident herbivore populations on the rise, it is projected that resident predators will also increase. On a larger scale, this is study is important for multiple reasons: in order to increase tourism to the refuge, to generate more knowledge on predators as a whole, not only vulnerable species such as cheetahs, and it also implies that the conservation goals of Enashiva have been successful thus far and could be expanded or borrowed in the establishment of similar private conservation areas.

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Appendix A:

Avian Carnivores	Mammalian Carnivores	Mammalian Insectivores	Reptilian Carnivores
Bateleur	Lion	Bat-Eared Fox	Black Mamba
Bustard	Leopard	Banded Mongoose	Unidentified Cobra
Augur Buzzard	Cheetah	Mongoose	Unidenified Lizard
Common Buzzard	Hyena		
Black-Chested Snake Eagle	Caracal		
Long-Crested Eagle	Serval		
Martial Eagle	Jackal		
Steppe Eagle			
Tawny Eagle			
Verreaux's Eagle			
Pygmy Falcon			
Sooty Falcon			
Dark Chanting-Goshawk			
Black-Shouldered Kite			
Secretary Bird			
African White-Backed Vulture			
Hooded Vulture			
White-Headed Vulture			
Unidentified Raptor			

Appendix B:

Mammalian Predator Species Occurring in the Serengeti not observed in Enashiva
Common Genet
Large Spotted Genet
African Civet
Aardwolf
African Wildcat
Wild Dog
Honey Badger
Zorilla
Ground Pangolin

Appendix C:

From April 10 to April 16, 2011, 32 walking transects were completed and 21 different mammal species below the top trophic level (gamma richness=21) were observed within Enashiva Nature Refuge. Four of these species were either domesticated or human. A total of 2985 wild individuals were counted. The transects covered a total area of 19.54 km^2, dominated by grassland and wooded grassland habitats (Figure 2a). This is slightly less area covered then in 2009 (25.92 km^2, Figure 2b).

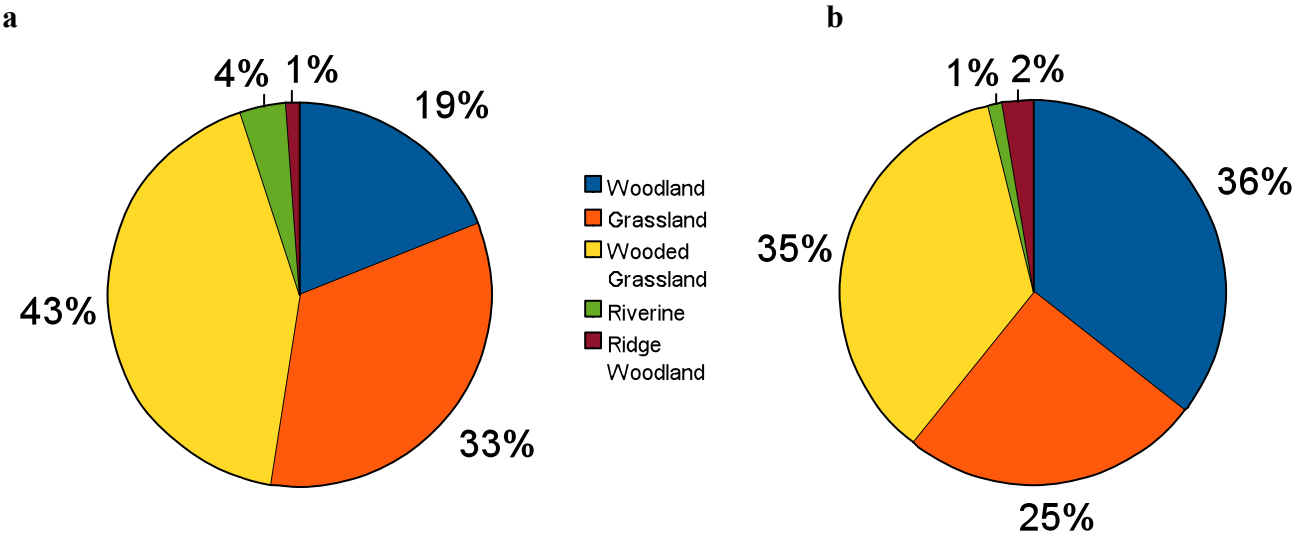

Figure 2. Total area surveyed in square kilometers. Chart a shows percent habitat surveyed in 2011, chart b percent surveyed in November 2009 (Butler 2009). Total area surveyed in 2011 was 19.54 km^2, divided into 32 walking transects. Data collected from April 10-April 26, Enashiva Nature Refuge, Tanzania.

The number of species observed in each habitat (alpha richness) was comped to results from November 2009 (Figure 3), keeping in mind that data from 2009 includes carnivores, while current data includes mammals below the top trophic level only. The highest alpha richnesses in 2011 were found in the grassland and wooded grassland habitats (12 and 13 respectively).

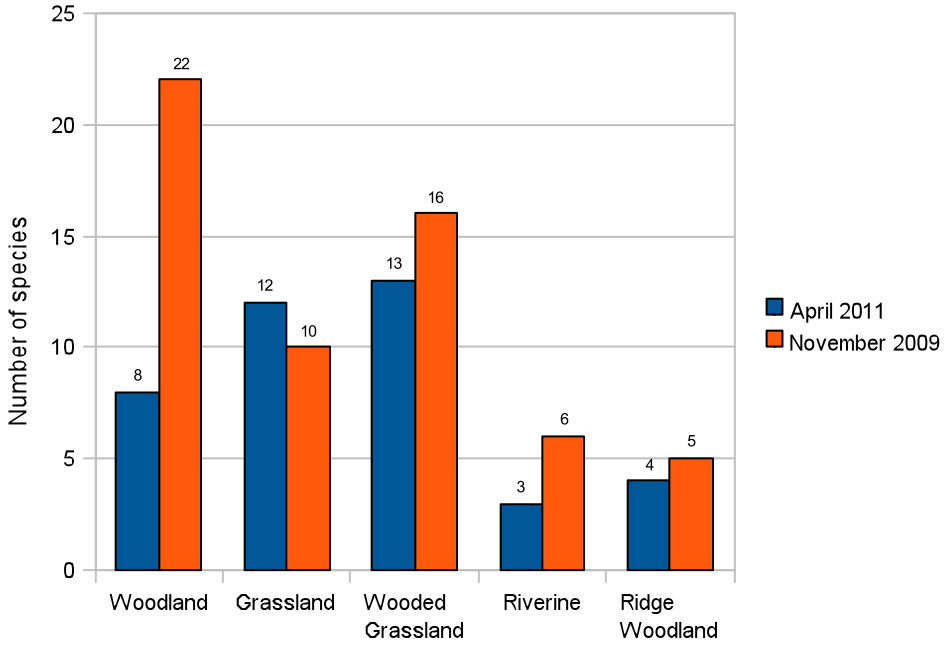

Figure 3. Alpha richness by habitat, April 2011 and November 2009. Data collected during 32 walking transects from November 9-24, 2009 (Butler 2009) and April 10-26, 2011 at Enashiva Nature Refuge, Tanzania. 2009 data includes mammals in the top trophic level.

Density of mammals below the top trophic level at Enashiva was calculated as 152.76 animals per square kilometer overall in April 2011. Densities by habitat were calculated as: 30.54 individuals/km^2 in the woodland, 250 individuals/km^2 in the grassland, 145.56 individuals/km^2 in the wooded grassland, 18.92 individuals/km^2 in the riverine, and 40.91 individuals/km^2 in the ridge woodlands. These results are divided by feeding ecology and compared to those from November 2009 in Figure 4.

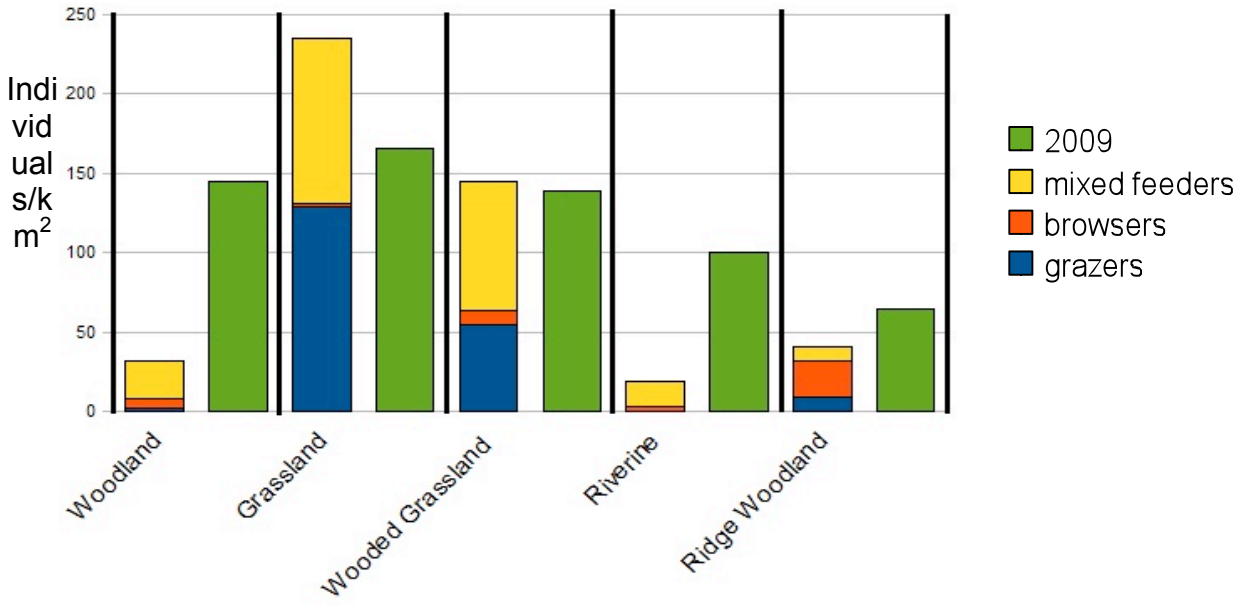

Figure 4. Density of individuals (n=2985 in 2011, n=3334 in 2009) by habitat and feeding ecology. Data collected April 2011 at Enashiva Nature Refuge, Tanzania. Results from November 2009 (Butler 2009) include mammals in the top trophic level.

Simpson's Index of Diversity (SID) was calculated at 0.801 overall for the data collected in April 2011. The index was also calculated by habitat, and compared to past data in Table 1.

Habitat	Simpson's Index of Diversity April 2011	Simpson's Index of Diversity November 2009	Simpson's Index of Diversity November 2008
Total	0.801	0.815	0.815
Woodland	0.588	0.829	0.784
Grassland	0.712	0.706	0.723
Wooded Grassland	0.778	0.771	0.807
Riverine	0.571	0.725	0.653
Ridge Woodland	0.691	0.771	0.761

Table 1. Simpson's Index of Diversity by habitat. Data collected during 32 walking transects, each set completed in April 2011, November 2009 (Butler 2009), and November 2008 (Altman 2008) at Enashiva Nature Refuge, Tanzania. Data from 2009 and 2008 includes mammals in the top trophic level.

Community similarity was calculated between habitats at Enashiva, and compared to data from November 2009 (Figure 5). The most similarity in 2011 was found between wooded grassland (n=13) and grassland (n=12) at 92.31%. All other habitats had similarities below 50%, the lowest being between wooded grassland (n=13) and ridge woodland (n=4) at 13.33%.

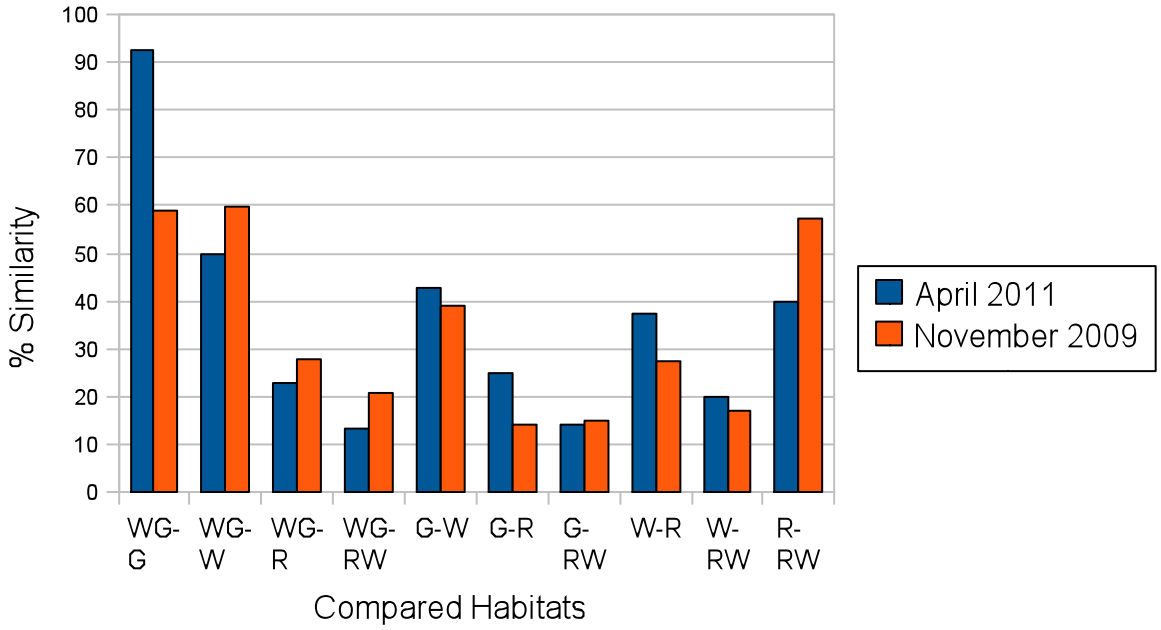

Figure 5. Community similarity among habitats at Enashiva Nature Refuge, with data collected in April 2011 and November 2009 (Butler, 2009). WG= woooded grassland (n=13), G=grassland (n=12), W=woodland (n=8), R=riverine (n=3), RW= ridge woodland (n=4).

For mammals with visible and observed young, the ratio of adults to juveniles was calculated and compared to November 2009 (Figure 6). The April 2011 percentage of young to adult individuals was 44.44% (12/27) for warthogs, 5.72% (29/507) for impala, 30.74% (158/514) for zebra, 52.17% (12/23) for baboons, 4.24% (32/754) for thomson's gazelle, 50% (20/40) for giraffe, 30.19% (141/467) for wildebeest, 3.13% (3/96) for eland, and 4.08% (2/49) for grant's gazelle.

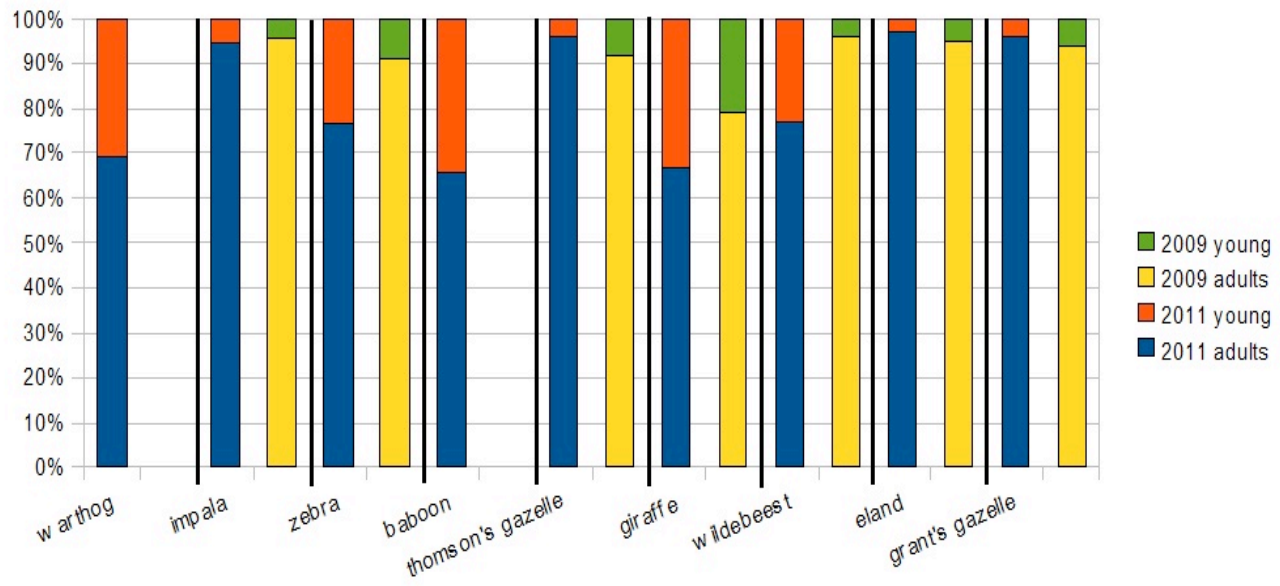

Figure 6. Percentage of young versus adults for selected species, compared to data from 2009 (Butler 2009). For warthog: n=27, impala: n=507, zebra: n=514, baboon: n=23, thomson's gazelle: n=754, giraffe: n=40, wildebeest: n=467, eland: n=96, grant's gazelle n=49. Data collected April 2011 at Enashiva Nature Refuge, Tanzania.

Some species, like the thomson's gazelle, showed noticeable variation in presence of young. Most of the juvenile thomson's were seen in the last few transects completed in April 2011 (See figure 7). No other species showed any trend based on date.

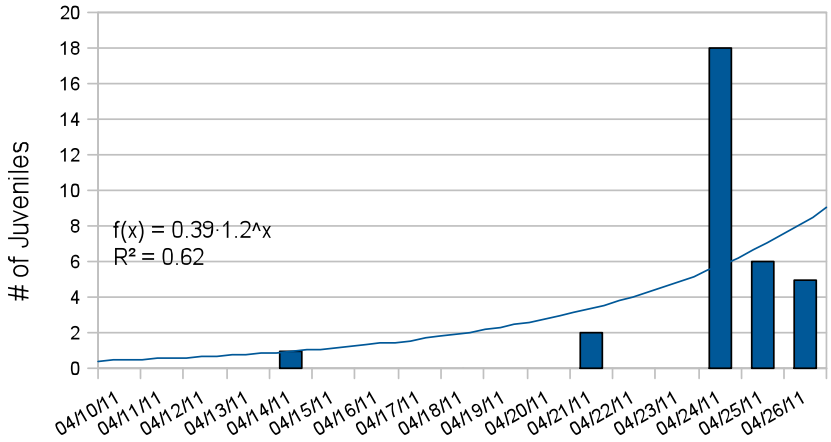

Figure 7. Number of juvenile Thomson's gazelles observed per date (n total=32), fitted with a regression line. Data collected April 10-26 2011 during 32 walking transects, at Enashiva Nature Refuge, Tanzania.

The species observed at Enashiva were compared to a list of mammals found in Serengeti National Park (Figure 8). A list of diurnal mammals below the top trophic level was compiled (Table 2) for better comparison.

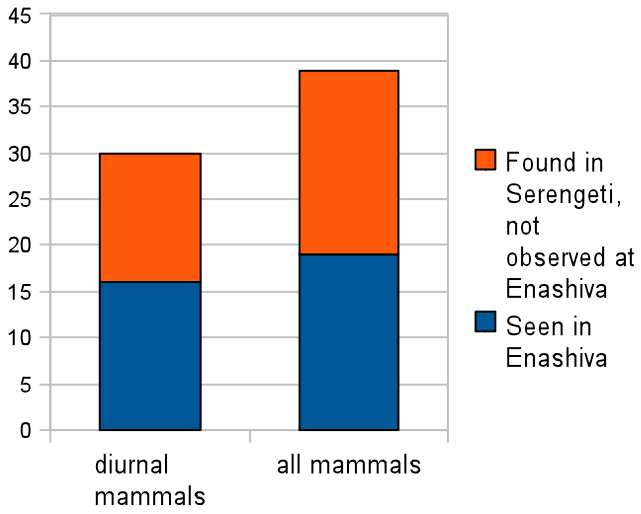

Figure 8. Number of species of mammals below the top trophic level found in the Serengeti and observed at Enashiva. N= 30 diurnal species listed in the Serengeti, N=38 total mammals below the top trophic level in the Serengeti.

Diurnal Mammals below the top trophic level found in the Serengeti not seen in Enashiva	
Patas Monkey	Black and white Colobus monkey
Bush hyrax	Rhino
Elephant	African buffalo
Hippopotamus	Duiker
Klipspringer	Steenbock
Roan	Waterbuck
	Oryx

Table 2. Diurnal mammals found in the Serengeti not observed at Enashiva Nature Refuge during 32 walking transects from April 10-26, 2011.